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DECLINING INTERSTITIAL TRANSSUDATION IN MAN

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16. Abstract Starling-Landis concepts of formation of interstitial fluids are in agreement with measurements of calf volume in normal young women, in horizontal recumbency or after horizontal immersion. The volume of the calf is reduced when the hydrostatic pressure of the blood column is diminished under the phlebostatic level and when the external pressure is increased by the hydrostatic pressure of the water bath.		
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DECLINING INTERSTITIAL TRANSSUDATION IN MAN

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Passage from the horizontal to the vertical position in a normal /165* human involves a decrease in plasmatic volume which reaches 6.4 % after 20 minutes [1]. It is explained by an augmentation in the filtration pressure at the level of the capillary exchange beds. This increase depends on the hydrostatic pressure exercised by the blood column on the parts of the body located below the plane of the right auricle [2]. In this way the concepts are verified which were elaborated by Starling-landis for realizing the formation of interstitial liquids and for their excahnge with the circulating plasma [3,4].

For the excess filtered liquid to leave the plasma, an augmentation in the interstitial volume must be involved. This is what we have verified a contrario in measuring the calf volume after passage from the vertical station to the horizontal position at first, and then after the action of immersion.

Techniques /166

1. One hundred tests have been performed during a period of more than a year on 100 young women, ranging in age from 18 to 27, normal, and not subject to edema at the end of the day. The time of menstrual cycle was not taken into consideration.

2. At time zero the subject, wearing a bathing suit, enters a location heated to 24.5°C, at 60 % humidity, keeping a light covering on the shoulders if necessary. There she receives the instructions and undergoes the preparation time of 15 minutes in an upright position. An initial measurement of the volume of one of the calves - always the same one in the series - is performed then (V_a). After this the subject sits down, adopting the position she will remain in later on in the bath:

*Numbers in the margin indicate pagination in the foreign text.

trunk vertical, well supported, lower limbs stretched horizontally in relaxation. After 30 minutes, one proceeds to a second determination of the calf volume (V_b). The subject finally sits down in a bath filled with fresh water at 35°C (lukewarm), keeping strictly the same position as in the air. The water level is raised up to the shoulders. After having remained immobile during 20 minutes in the lukewarm bath, the subject undergoes a final measurement of calf volume (V_c).

3. V is measured by means of a plethysmographic technique [5] validated in our laboratory. The segment being considered is delimited by anatomical marks carefully traced prior to the experiment, generally 3 cm on the lower side of the tibial plate and at the upper limit of the external malleolus. These plethysmographic determinations display good reproductivity: the variations between tests do not exceed 0.1 % of the mass of liquid displaced, with the temperature of the plethysmographic fluid fixed at 35°C.

Each measurement of the volume - which takes 3 to 4 minutes maximum - necessitates a radical change in the position of the subject, since the plethysmographic determination is performed with the subject standing upright, the lower limbs submerged vertically in the tub of the apparatus.

During this determination certain alterations in the blood mass naturally take place. The duration of this determination is too brief for the interstitial mass to be affected, as Juchmès et al. have experimentally verified [4].

4. Our experimental plan permits one to determine the influence of the horizontal placement by calculating V_a-V_b; V_b-V_c expresses the influence of immersion combined with that of the horizontal position assumed previously.

The statistical significance of the average differences has been calculated according to the formula of Student for coupled values.

<u>Results</u>

The variations in the calf volume are compiled in Table 1. One

may read there the differences together with the movements causing them and their statistical significance. It is thus shown that the passage into a semi-horizontal position involves a decrease in the volume V_a-V_b of 29 ml (which would be 1.25 % of V_a). The immersion taking place after the effects of assuming horizontal position brings about V_c with a supplementary reduction of 28 ml; this amounts to a cumulative decrease of 57 ml in comparison with V_a (3.77 % of the initial volume V_a).

The variation in volume V_a-V_b induced by assuming a horizontal position in air is statistically significant; the difference following immersion is equally significant (V'_b-V_c), and, a fortiori, V_a-V_c. /167

TABLE 1. VARIATIONS IN CALF VOLUME FOLLOWING IMMERSION

Situation	Number	Variations (ml)*	Significance
Control	V_a 100	V_a - V_b 29 ± 11,2	2 p < 0,02
After assuming horizontal	V_b 100	V'_b - V_c 28 ± 9,8	2 p < 0,01
After immersion	V_c 85		

*Differences are average and are standard-error.

V'_b is different from V_b because 15 subjects did not undergo immersion for accidental reasons.

Discussion

1. The entire rapid decrease in the calf volume, since the characteristics of the blood circulation are not modified, may only be interpreted by admitting that the mass of the interstitial liquids has been reduced in the interval. The same reduction is explained by a temporarily amplified transendothelial resorption, coupled or not with a retarding in filtration. The forces which organize the endothelial transport are represented, in the first approximation from Starling, by the following relation: $\dot{Q}_1 = K\,(P_H + \varrho\, g\, h - P_t) - (\pi_p - \pi_t)$.

The transendothelial output $\mathring{Q}_1$ is determined in magnitude and direction by the algebraic sum of the filtration forces: hemodynamic pressure (P_H) and hydrostatic pressure connected with the body position ($\varrho\, g\, h$), decreased by the external pressure (P_t) and the forces of resorption, which are plasmatic of an oncotic nature (π_p), from which is subtracted the oncotic pressure of the interstitial liquid (π_t). The factor K

represents the characteristics of semi-permeability of the endothelial wall at the point being considered.

The relation of Starling-Landis is an approximated expression, since it is only valid for an infinitely brief interval of time. In other respects, in order to pass the same instantaneous output on to a permanent variation in volume, it would be necessary to understand that the data are technically impossible to collect, e.g. the connections between the volume of the limb and its average interstitial pressure.

Based on these reservations, the statement has been modified in the course of our tests: the factor ϱ g h diminished by the passage to a horizontal position; P_t augmented by the hydrostatic counterpressure of the bath water. These two modifications operate in the same direction: they retard the filtration and facilitate resorption. Nevertheless, the changes which affect these forces cannot be calculated with the total precision desired: the geometric center of the limb segment under consideration is impossible to establish; the position of the /168 phlebostatic plane, from which all the measurements of the hydrostatic gradient have been produced, is only approximated; likewise, the raising which this plane is subject to at the time of immersion.

2. Based on the biological characteristics of our subjects, the passage to the horizontal reduces the filtration pressure on the average to about 50 cm H_2O, involving the loss of an interstitial volume of 1.25 %. Upon immersion in lukewarm water, the hydrostatic pressure equals 60 cm on the average. It joins its effects to the anterior reduction in the filtration pressure dependent on the abandonment of orthostatism. The total resorption amounts to 3.77 %: V_a-V_c.

The variations that one may thus evince in the interstitial volumes in the above tests are naturally limited: the changes they undergo are explained by rapid transfers induced passively. One may easily interpret them by using as the as the first approximation the Starling-Landis relation, as Hagan et al. moreover admit [1].

Conclusion

The changes in volume which are induced at the level of the calf in normal subjects by the bodily position and immersion in lukewarm water can be explained according to the concepts defined by Starling-Landis.

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